JWST ISIM Primary Structure and Kinematic Mount Configuration

Andrew Bartoszyk, Tim Carnahan, Steve Hendricks, Charles Kaprielian, Jonathan Kuhn, Cengiz Kunt

The JWST Integrated Science Instrument Module (ISIM) includes a large metering structure (approx. 2m x 2m x 1.5m) that houses 4 instruments and a substantial dewar. The total ISIM mass is 1300-1400 kg, including an allocation of 300 kg (21-23%) for the structure, and the ISIM first mode frequency requirement is 25 Hz. The structure mounts to the back of the JWST primary mirror structure, and the on-orbit nominal operating temperature is in the range of 32-37 K, with on-orbit shifts of .5 K during operation.

Stringent dimensional stability and repeatability requirements combined with mass limitations led to the selection of a composite bonded frame concept comprised of biased laminate tubes with axial Young's Modulus of greater than 30 msi (207 GPa). Even with the superb material specific stiffness, achieving the required frequency for the given mass allocations in conjunction with severe spatial limitations imposed by the instrument complement and the Optical Telescope interface has proven challenging. In response to the challenge, the ISIM structure team considered over 100 primary structure topology and kinematic mount configurations, and settled on a concept comprised of over 70 m of tubes, over 50 bonded joint assemblies, and a "split bi-pod" kinematic mount configuration.

In this presentation we will review the evolution of the ISIM primary structure tube topology and kinematic mount configuration to the current baseline concept. We will also show optimization procedures used and challenges resulting from complex joints under launch loads. Two additional key ISIM structure challenges of meeting thermal distortion and stability requirements and metal-composite bonded joint survivability at cryogenic temperatures are covered in other presentations.

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Jonathan Kuhn, Tim Carnahan
NASA/GSFC Code 542

Andrew Bartoszyk, Steve Hendricks, Charles Kaprielian, Cengiz Kunt
Swales Aerospace

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Outline

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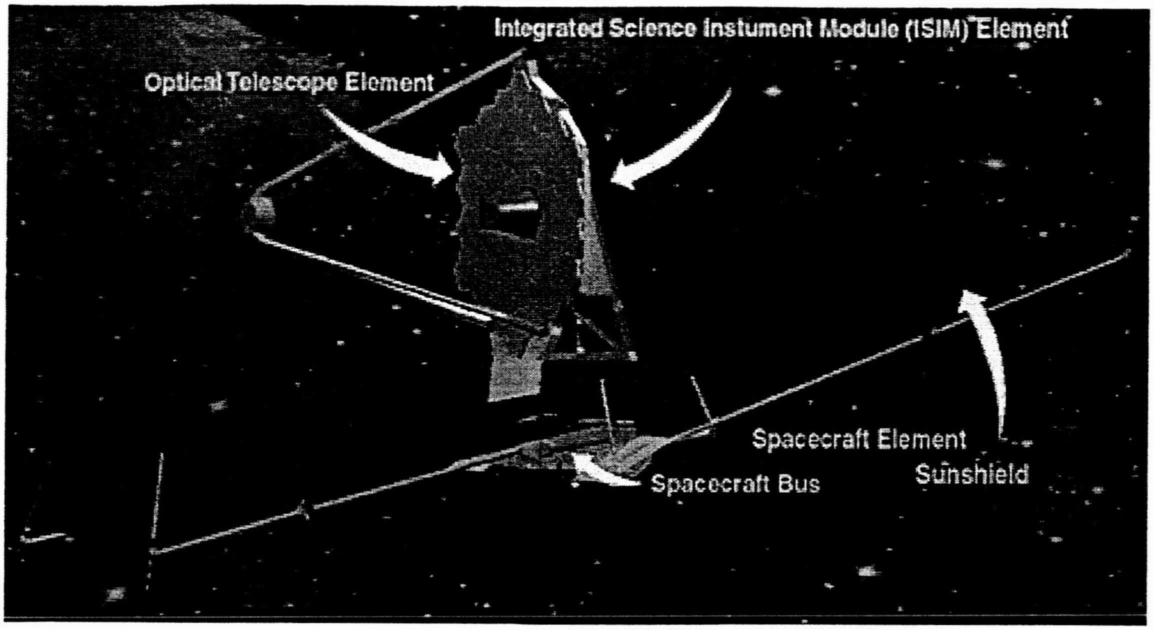
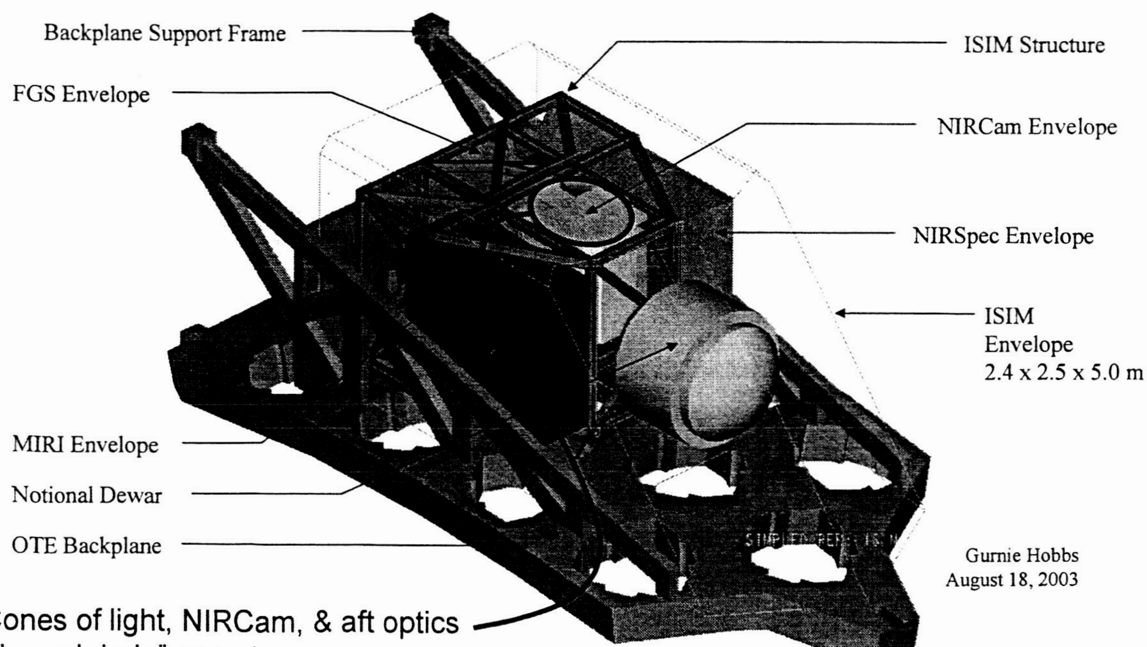
  - **JWST, ISIM, & ISIM Requirements**
- **Structural Evolution**
- **Current Concept**
  - **Tube topology, mode shapes, & kinematic mounts configuration**
- **MSC/NASTRAN Optimization**
- **Conclusion**

JWST
James Webb Space Telescope



Courtesy of John Nella, et al. Northrop Grumman Space Technology

ISIM
Integrated Science Instrument Module



Cones of light, NIRCam, & aft optics "through hole" open bay

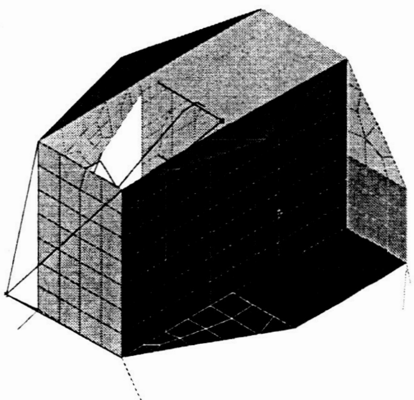
ISIM Structure Requirements

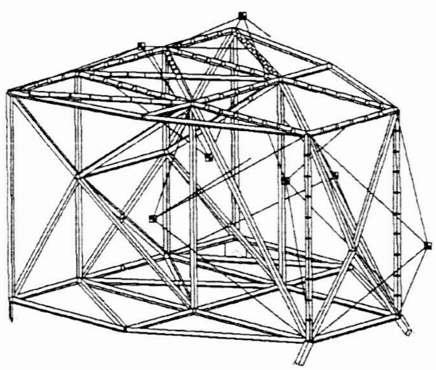
- Driving requirements:
  - Instrument interfaces, access, & volume
  - Mass:
    - Total: 1400 kg
    - Structure: 300 kg (~21%)
  - Fixed base first mode frequency ≥ 25 Hz
    - 35 Hz w rigid SI's & Joints
  - Nominal operating temperature: 32 K at BOL
  - On-orbit temperature shift: ~0.5 K
  - Instrument on-orbit stability (~200 nm, 120 milli-arc-seconds)
- Challenges:
  - Mass/stiffness/interface balance
  - Complex all-composite joints
  - Metal/composite joint survivability
  - On-orbit stability of heterogeneous structure

Goal: No removable structure

Structure Evolution

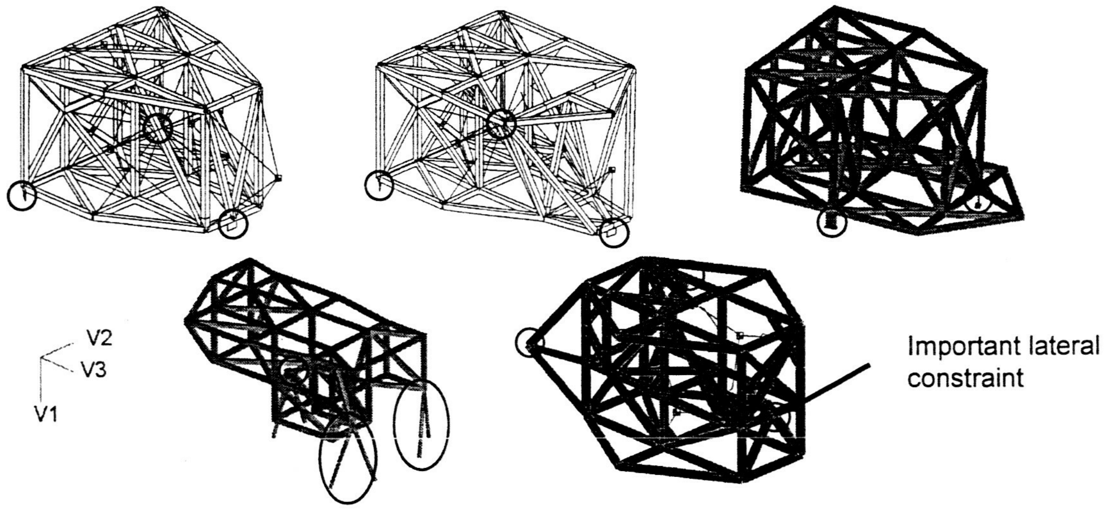
- Material: Considered Composite, Aluminum, Beryllium, AlBeMet
  - Composite selected for dimensional stability and specific stiffness
- Construction: Considered Frame vs. Panel
  - Unoptimized frame with tube axial modulus of 30 Msi weighs ~160 kg
  - Optimized panel with quasi-isotropic facesheet modulus of 17 Msi weighs ~225 kg





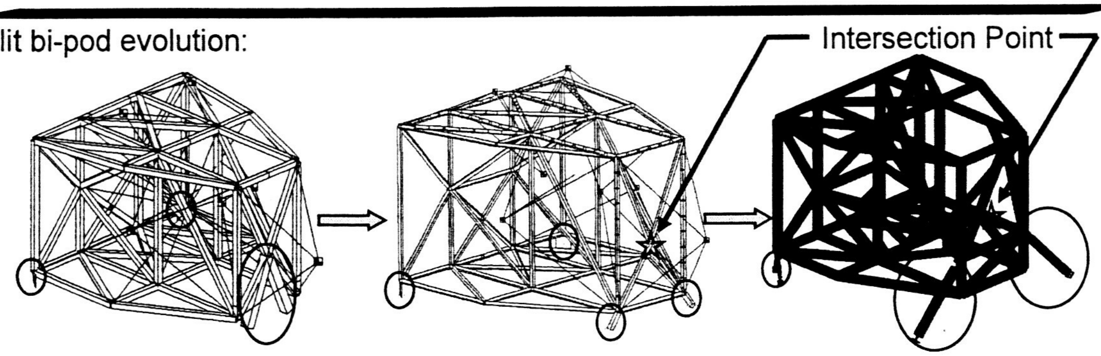
Structure Evolution

- ISIM/OTE interface configuration is critical to ISIM frequency & mass
- Started with 3 point interface, considered many options
- Found that a lateral constraint near projected CG on +V3 end is important due to the through hole open bay

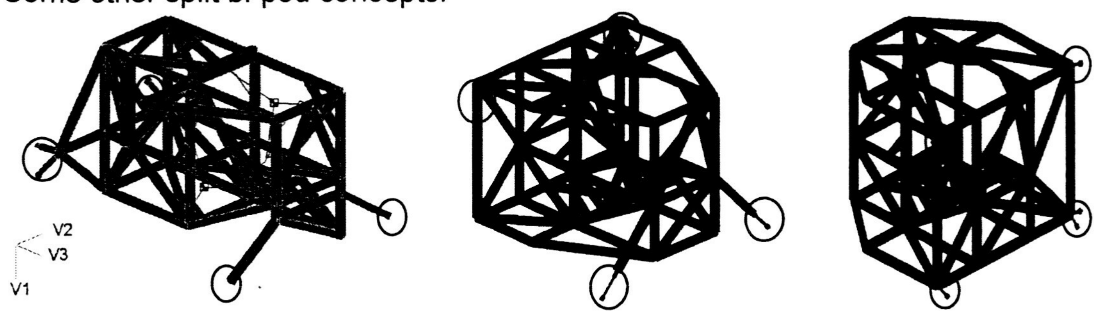


Structure Evolution

Split bi-pod evolution:

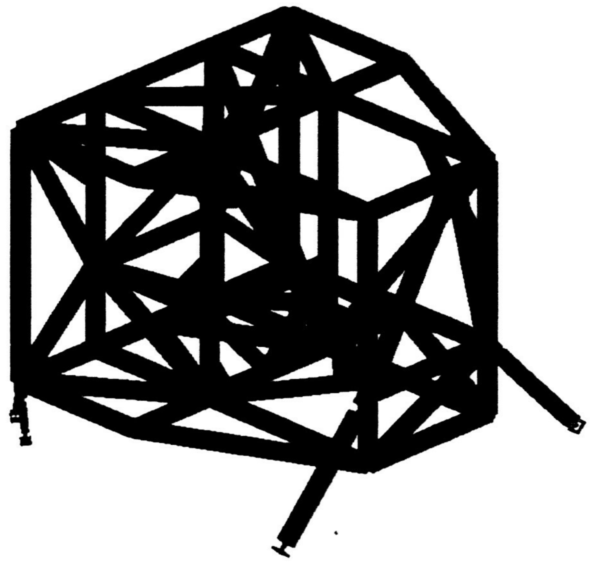


Some other split bi-pod concepts:

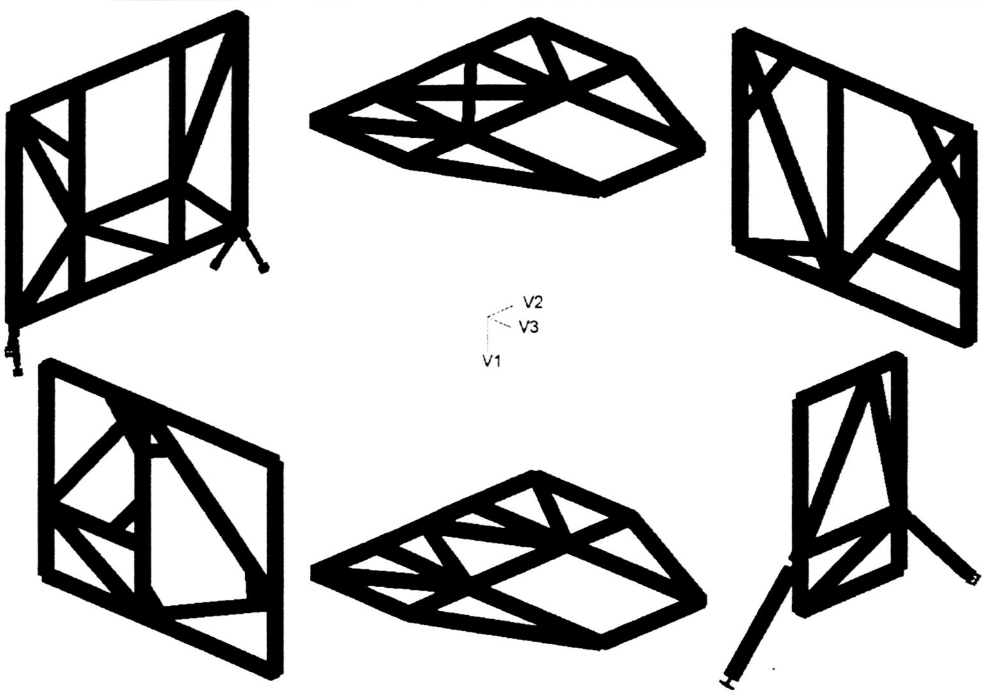


Current Concept

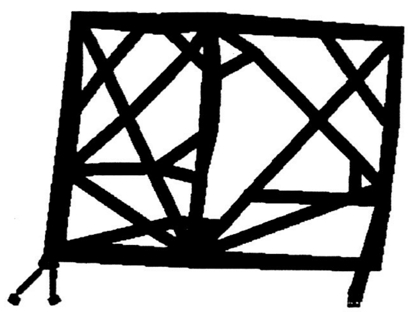
- Frequency: 32.3 Hz
  - rigid joints & 50 Hz instruments
- Tube mass: 160 Kg
- Tube length: 78.5 m
- Tube section: 75 x 75 mm
- Tube wall thickness: 4.6 mm
- Number of joints: 59
  - Including SI landing pads



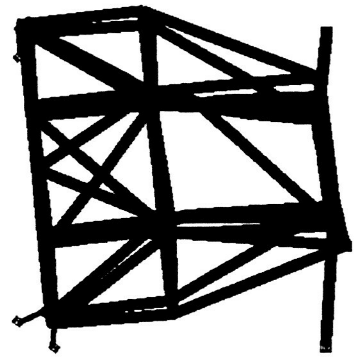
Current Concept



Mode Shapes



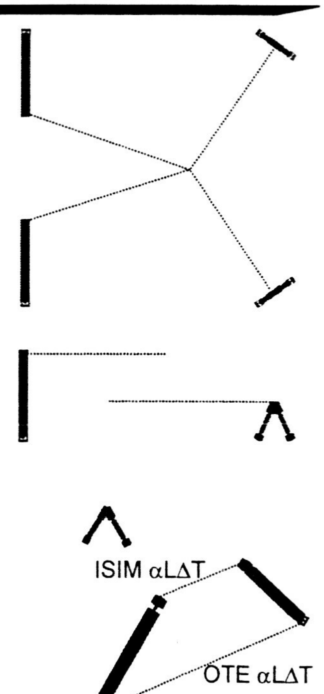
Mode 1: 32.3 Hz



Mode 2: 36.3 Hz

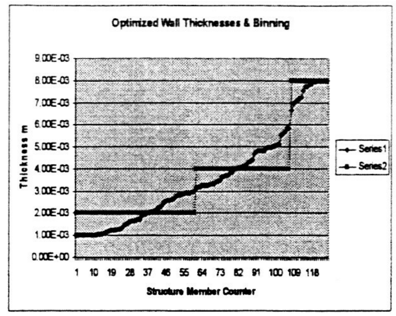
Kinematic Mount Configuration

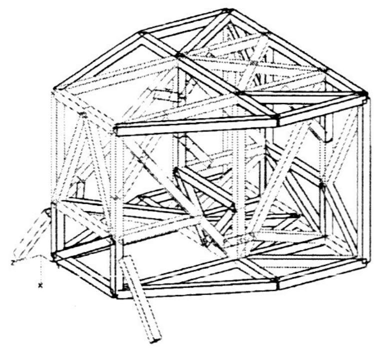
- 6 monopod constraints
  - 2 sets of bipods
  - 1 "split bipod"
- Idealized/pinned mounts are statically determinant
- Rigid rotation on bulk cooldown due to:
  - Line of action mismatch
  - ISIM/OTE differential strain
- Rigid rotation plus over constrained torsional flexure stiffness results in secondary axial loads
- Rigid rotation currently within requirements
- May tune monopod design to counteract rotation if needed



MSC/NASTRAN Optimization

- Panel concept
  - Iterate between:
    - ★ Manual panel layout
    - ★ Facesheet thickness optimization using NASTRAN optimizer
- Tube wall thickness
  - Discrete optimization did not work well for this application – slow convergence and impractical results
  - Tube wall thickness optimization in specified range using NASTRAN optimizer
  - Manually group wall thicknesses into "bins"
  - Developed a perl script to automate the process





MSC/NASTRAN Optimization Applications

- Joint effective stiffness
  - Used NASTRAN optimizer to tune springs in effective joint models
- Primary structure topology
  - Attempted "topology" optimization by using a fine mesh and letting stiffness go to zero
  - Need ability to turn elements on/off during optimization to be effective